

PERCEPTIONS AND REALITY: ONE TEACHER'S USE OF PROMPTS IN MATHEMATICAL DISCUSSIONS

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We examined one primary teacher's knowledge for facilitating mathematical discussion (MKT-Disc) via approximations of practice and compared her use of certain questioning prompts in these vignettes with her facilitation of discussions in her actual mathematics teaching. Findings showed differences in what the teacher reported she knows and what she actually did in practice. Evidence suggests the teacher's institutional obligations to a mandated curriculum, as well as the nature of her MKT-Disc, were the primary reasons for the mismatch between approximations and actual practice.

BACKGROUND AND OBJECTIVES

Teachers' use of questioning to facilitate mathematical discussions has been a topic of interest in much of the literature (Boaler & Brodie, 2004; Hiebert & Wearne, 1993). Much of this research has identified various ways of questioning that are more effective in promoting students' mathematical understandings and achievement. However, certain issues have problematized applying what research has uncovered as more effective mathematics pedagogy, and what teachers do in the classroom. A growing body of research suggests discrepancies between what researchers describe as effective questioning and classroom teachers' interpretations of such descriptions (Hill, 2005; Kosko et al., in press). Yet another issue lies in the potential discrepancy between what a teacher *knows* and what they actually *do* in their teaching. Specifically, teachers' questioning to promote mathematical discussion can be considered as a form of pedagogical content knowledge, and such knowledge is only pragmatically useful if it can be applied to pedagogical practice. Hill et al. (2008) observed relationships between teachers' mathematical knowledge for teaching (MKT) and their quality of instruction, and Kersting (2008) has observed similar connections in her use of vignettes to measure MKT. So, it appears that teacher knowledge does inform practice. Yet, teachers are influenced by a myriad of factors, stakeholders and context-specific conditions (Herbst & Chazan, 2012). Such influences may impose restrictions on how able a teacher is to apply what they *know* to be effective pedagogy in their classroom. The present study describes the case of a primary grades teacher with higher than average MKT and a disposition towards using dialogic mathematics discourse. The purpose of this study is to explore whether the teacher's conceptions of appropriate mathematical discussion aligns with her facilitation of such discussions in her classroom.

TEACHER QUESTIONING

One of the primary means for teachers to facilitate mathematical discussion is through the purposeful use of effective questioning practices. Kazemi and Stipek's (2001) observations of four upper primary teachers in the U.S. revealed a connection between a press for meaning via questions that solicited explanation and justification with deepening students' mathematical understandings. Supporting these observations, Hiebert and Wearne (1993) observed six early primary grades teachers and found that students whose teachers elicited more explanation and justification via questioning had higher mathematics achievement. Boaler and Brodie (2004) refer to such questions that solicit explanation and justification as *probing* questions. While probing questions are generally encouraged by findings from observational and empirical studies, another form of questioning is much more prevalent. Referred to as *gathering information* questions by Boaler and Brodie (2004), such prompts solicit factual/answer-only responses, recalled/memorized procedures, and similarly simplistic mathematical statements. Gathering information prompts are the dominant form of questioning by teachers in math lessons in the U.S., and while such prompts may provide opportunities to stimulate discussion in certain contexts, probing questions are more consistent in eliciting deeper descriptions of mathematics (Temple & Doerr, 2012).

While the literature generally supports the more prevalent use of probing questions, recent research has suggested inconsistencies between researchers' descriptions of appropriate questioning and some teachers' interpretations of such descriptions (Hill, 2005; Kosko et al., in press). This has led some researchers to argue for a more explicit approach to teacher education in facilitating mathematical discussions, particularly via questioning approaches (Boerst et al., 2011; Kosko et al., in press). One such specification applied here is the conceptualization of such questioning as a particular domain of teacher knowledge composed primarily of what Ball et al. (2008) would refer to as *knowledge of content and students* (KCS) and *knowledge of content and teaching* (KCT). Thus, using questioning to facilitate mathematical discussion is one portion of a subdomain of MKT which we refer to as MKT-Disc (although, MKT-Disc may also include revoicing, task selection, etc.). Relationships between MKT and more effective use of questioning have been observed by qualitative studies (e.g., Hill et al., 2008) and more recently by quantitative analysis (Kosko, in review). Yet, as argued by Kosko (in review), such relationships may be more pragmatic in defining teacher questioning as a domain of knowledge. As such, MKT-Disc requires the teacher to utilize, often simultaneously, KCS in listening and decoding student responses in discussions and KCT in framing an appropriate prompt to both attend to the student's thinking and facilitate the general instruction of mathematics at hand for the whole class. The appropriate use of probing questions is only one element of MKT-Disc, and its complexities extend our brief review here. Yet, questioning is widely researched and, therefore, an appropriate gateway to examining MKT-Disc. For this reason, it is the central focus of the present study.

TEACHER PERCEPTIONS VERSUS ACTUAL PRACTICE

Research on teacher perceptions (beliefs and knowledge) has shown that in certain cases, teachers' perceptions align with their practice; while in other cases there is inconsistency (e.g., Kuhs & Ball, 1986; Stipek et al., 2001). For example, Stipek et al. (2001) found primary teachers beliefs about mathematics teaching correlated with their students' perceptions about mathematics. Following a review of literature, Kuhs and Ball (1986) argue that inconsistencies between teachers' beliefs and practice can be explained by their level of mathematical knowledge. Pajares (1992) suggests that internal (e.g., beliefs) and external (e.g., school/administrative) factors mediate beliefs and practice, thus causing some dissonance between teacher beliefs and practice. Given the potential both for alignment and misalignment between perceptions and practice, the current study examines the case of one teacher to ask:

Do conceptions of using probing questions align with actual practice?

METHODS

Data was collected from a grade 3 teacher in the Midwestern U.S. whom we refer to as Mary. Mary was an early career teacher (2 years experience) with a Bachelors and Masters degree in education. She taught in a school district using Saxon Math curriculum. In the year data was collected, Mary indicated that district expectations were to adhere to the curriculum materials stringently. Mary participated in a two-phase study in which a larger sample completed a survey packet with open and closed response items regarding dispositions and knowledge for facilitating mathematical discussion. After completing the survey packet, Mary was randomly selected for the second phase of data collection which involved observing 10 of her mathematics lessons. The goal of the second phase of study was to compare teachers' actual practice with findings from the survey packet. For the present study, we report on data from both phase one and two.

Phase One: Data from Survey Packet

The survey packet included items assessing knowledge and dispositions regarding facilitation of mathematical discussion, as well as some background information. We briefly describe some measures here, along with descriptive indicators for Mary. One measure was Truxaw et al.'s (2010) assessment of teachers' dispositions for dialogic discourse. Mary's score of 3.67 (*Range* = 1.00 to 4.00) indicated a strong disposition towards supporting dialogic discourse. Mary also had a higher than average score for MKT as assessed by a 2006 version of Hill et al.'s (2004) assessment (*IRT Score* = 1.72 where a score of 'average ability' is 0.00). In addition to these measures, Mary completed one open-response question asking "What are the essential things a teacher must do to facilitate mathematical classroom discussions so they are effective in helping students' understanding of the content?" This open-response prompt was followed by three incomplete vignettes which Mary and other participants were asked to complete so they were 'model' vignettes of teachers facilitating mathematical

discussions. While we provide excerpts of Mary's responses in the analysis and results section, the general nature of her descriptions were supportive of using probing questions to solicit explanation and justification from students. Lastly, we presented Mary and other participants with three cartoon-based vignettes in which they were asked to select one of four provided prompts that would best aid students' understanding in the discussion. In two of the three vignettes, Mary selected a probing question (see Kosko, in review for analysis of all Phase One participants). Responses Mary provided in the survey packet indicated a disposition towards facilitating mathematical discussions, aligned with a higher than average level of MKT.

Phase Two: Observations of Whole Class Mathematical Discussions

Observational data was collected from 10 class sessions over three weeks in Spring 2013 via video and audio recording and were transcribed. Segments of recordings were selected that included whole class discussions generally about 25 minutes in length. Both authors coded Mary's questioning following Boaler and Brodie's (2004) rubric. Coding reliability was sufficient ($Kappa = .61$) and differences were reconciled before analysis. For purposes of space and simplicity, we limit discussion of all coding for Mary's questioning to gathering information ($n = 323$; 89.5% of all prompts) and probing questions ($n = 19$; 5.3% of all prompts) across the 10 observations. However, descriptive statistics for all question types is reported in Table 1.

Gather Info	Insert terms	Explore math meaning	Probing	Generate Disc.	Link & apply	Extend think	Orient & focus	Establish context
323	3	9	19	5	1	0	1	0
89.5%	0.8%	2.5%	5.3%	1.4%	0.3%	0.0%	0.3%	0.0%

Table 1: Descriptive statistics for Mary's questioning across 10 observations.

ANALYSIS AND RESULTS

We examined Mary's responses from the survey packet and her use of questioning as coded in the transcripts from observational data. Our intent was to examine areas where there was overlap in Mary's perceptions via beliefs and knowledge with her actual pedagogy. To do this, we first attended to Mary's responses to the open and closed response items that included approximations of practice (i.e., vignettes). The open response items included one general question asking teachers to describe the essential things a teacher must do to facilitate mathematical discussions. Among other features, Mary's response included the following statement related to teacher questioning: "teachers must encourage students to explain their thinking so that teachers can correct misconceptions." Mary also provided responses to three incomplete vignettes, of which an example is shown in Figure 1. Mary's response is also shown, with her use of prompts in bold.

Incomplete Vignette:

Mr. William's 2nd grade class is discussing the problem $80 + 15 + 5 = \square + 60$. Jared blurts out "twenty plus fifteen plus five makes forty!" Keisha replies, "but you've got to do it in order!"

Mary's Response:

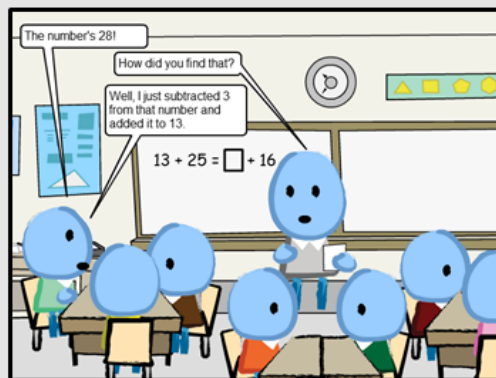
Jared, please explain your thinking. I see 15 and 5 in the problem, but not 20 - why did you think to add 20? Let Jared explain + correct any misconception. **"Keisha, what did you mean when you said 'you've got to do it in order'?"** Let Keisha explain her thinking and be sure to clarify, "The commutative property says that it does not matter in what order we add numbers."

Figure 1: Mary's response to the first incomplete vignette.

Mary's response in Figure 1 includes a probing question for both hypothetical students, Jared and Keisha. This is followed by a description that infers a check for understanding. Mary provided a similar description for another vignette. Taken together with her response to the general prompt, Mary's descriptions suggest a conception of using probing questions primarily as a means to assess students' mathematical thinking. Her response to the third incomplete vignette, however, demonstrated a dominant use of gathering information prompts, but no use of probing questions. One potential reason for this is the nature of the vignette stem. Specifically, the third incomplete vignette includes a student's description of mathematics where in the other vignettes, students provided only answers initially. Thus, Mary appears to be using probing questions to solicit student's thinking, but when such thinking is present she is comfortable with the use of gathering information questions.

Mary's answers to the closed response vignette items provide support for this assessment. Figure 2 provides an example of one such item which, like the third incomplete vignette, includes a student's description in the vignette. Mary's response to this scenario was to select option 4, a gathering information prompt. Interestingly, the other two closed response items did not include initial student descriptions of their mathematics, and Mary selected options that were probing questions. Thus, from Mary's responses to these six vignettes, it appears Mary uses probing questions as a means to assess students' mathematical thinking, and uses gathering information questions when such thinking is apparent. Additionally, Mary provided responses to several survey items asking how frequently she used probing questions in her class discussions. Responses were along a Likert-scale (*1=Never/Hardly Ever; 2=Some Discussions; 3=About Half of Discussions; 4=Every/Almost Every Discussion*). Her response to each item was *Every/Almost Every Discussion*. Taken together, we can infer that Mary knows to use probing questions to elicit student thinking, and believes she does so in almost every mathematical discussion in her classroom. What is less apparent in examining her responses to vignettes is whether she knows to use probing *sequences* in certain contexts. As such, she has demonstrated both in the open and close response items that probing questions are only used to solicit student thinking, but not to press students for mathematical meaning.

Q80. In this scenario, Mrs. Patel is playing “guess my number” with her second-grade class when Katie tells her guess:



Mrs. Patel wants her students to have a solid understanding of the math involved. Of the options below, which would be the best question for Mrs. Patel to ask?

- ① “Does anyone have an opinion about what Katie did here?”
- ② “So Katie subtracted 3 from 25 and then added it to 13. Why do you think she subtracts and then adds the same number over here?”
- ③ “Katie, why did you subtract 3 from that number?”
- ④ “Katie, what number did you subtract 3 from?”

Figure 2: Example closed response item assessing teacher questioning.

We next compared Mary’s survey response data via approximations of practice (i.e., vignettes) with her questioning in her whole class discussions (i.e., actual practice). The discrepancy in actual use of probing questions and what Mary ‘knew’ or perceived to be appropriate use of probing questions was stark. To assess difference in frequencies in vignettes versus actual practice we used a Chi-Square analysis, which accounts for the different count data in each category and examines the distribution across the contingency table in Table 2. We found that the differences were independent from chance ($\chi^2(df=1)=25.78, p<.001$). As we alluded to earlier, Mary’s school district had strict curriculum requirements. Mary expressed the belief that these demands influenced her teaching and the nature of her class discussions. Specifically, she was concerned that the quality of her class mathematical discussions would not be as rich because she needed to keep pace with the curriculum guide. Findings from the Chi-Square analysis suggest her concerns may have been justified.

	Approximations of Practice	Actual Practice
Gather Information	45.5% ($n=5$)	92.9% ($n=404$)
Probing	54.5% ($n=6$)	7.1% ($n=31$)

Table 2: Comparison for use of gather information and probing questions.

We also compared Mary’s self-reported frequencies of using probing questions via survey items with explicit statements with the number of class discussions observed ($n=10$) where she used at least one probing question. Mary used probing questions in 40% of observed mathematical discussions. To assess whether this was a significant variation from her self-reported survey data, we used a binomial test and assumed that usage of probing questions *Every/Almost Every Day* would account for a minimum of 80% usage. Results indicated a statistically significant difference in perceived versus

actual use of probing questions in class discussions ($p=.006$). However, if Mary had selected the next frequent response available, *About Half of Discussions*, the binomial test would have found no statistical difference ($p=.75$). The difference in perceived frequency of probing questions versus actual frequency may be an over-estimation on the part of the teacher, not uncommon among those with reform-oriented beliefs. Yet, it may also represent a misalignment of Mary's conceptions of appropriate questioning practices in mathematical discussions with those advocated by researchers.

DISCUSSION AND CONCLUSIONS

Mary's responses to the open and closed response vignettes indicated both a disposition and knowledge for using probing questions to solicit students' mathematical thinking. However, observations of her facilitation of actual class mathematical discussions showed starkly different patterns in her use of probing questions and gathering information questions. The most obvious rationale for this difference between knowledge (via approximation of practice) and practice (via observation of practice) stems from descriptions Mary provided about curriculum demands. Namely, she was expected to follow a curriculum guide at a set pace as mandated by her school district. There is evidence to suggest that curriculum demands influence teachers' questioning (e.g., Boaler & Brodie, 2004). Herbst and Chazan (2012) classify such influences on teachers' decision making as *institutional obligations*, or obligations to institutional demands that teachers must adhere.

While it is tempting to identify the institutional obligation as the main reason for Mary's infrequent use of probing questions, data suggests additional influences. Mary's dialogic disposition and MKT scores were relatively high, but her responses to the vignette items indicated a specific understanding of questioning in mathematics. We surmise from her responses that Mary knows probing questions are useful for soliciting student thinking. However, when students have provided explanations, she did not elect to press for meaning either via vignette items or actual practice. Therefore, Mary's MKT-Disc may have included a gap in knowledge which could further explain her infrequent use of probing questions in actual practice.

The findings presented here are useful in continuing the work of understanding teachers' questioning strategies to facilitate mathematical discussion, and thus further conceptualize MKT-Disc. Further research comparing teachers of similar levels of MKT-Disc, but under different sets of institutional obligations, would help illuminate how such institutional demands interact with MKT-Disc. By further investigating this interaction, we believe the field will be better informed to improve teacher education and professional development efforts related to facilitating MKT-Disc.

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